BOWLER

Discriminative Efficiency for Varying Degrees of Brightness Intensity

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DISCRIMINATIVE EFFICIENCY FOR VARYING DEGREES OF BRIGHTNESS INTENSITY

BY

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THESIS

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1911

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THE GRADUATE SCHOOL

June 3, 1911

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Alida Cynthia Bowler

ENTITLED Discriminative Efficiency for Varying Degrees of Brightness Intensity

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Arts in Psychology

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DISCRIMINATIVE EFFICIENCY FOR VARYING DEGREES OF BRIGHTNESS INTENSITY.

The following study undertakes to determine: (1) the course of discriminative ability with visual stimuli of varying intensities, and (2) the maximum discriminative efficiency corresponding to an "optimal" brightness intensity.

Work along associated lines has been carried on by McDougall[1], and Froeberg[2], who have studied the effect of varying intensities of stimulation upon the time of reaction. McDougall, using darkness, 2 c.p. and 16 c.p. lamps, finds that reactions to auditory stimuli are more rapid, tho' less regular, in the state of darkness and of 2 c.p. illumination, than under 16 c.p. This indicates that there is an "optimal" intensity for reaction rapidity, and that this optimum lies at a very low point in the brightness scale. McDougall explains this as probably due to the influence of mental attitudes, conditioned by factors of novelty and attention. His work does not include observations as to the effect of correspondingly high intensities upon the reaction time. Froeberg, whose reactions are to the visual stimuli, noiselessly exposed, finds that the reaction time increases as the intensity of the stimulus decreases, that the shortest reaction

(1) McDougall, Robt. On the Influence of Varying Intensities and qualities of Visual Stimulation upon the Rapidity of Reactions to Auditory Stimuli. Amer. J. Physiol., 1903, 9, 116.

(2) Sven Froeberg. The Relation between the Magnitude of the Stimulus and the Time of Reaction. N.Y. 1907.

time corresponds to the highest intensity, with a gradual increase in reaction time with lowering intensities. Heoffers no explanation.

The results of this study indicate that there is an "optimum" brightness for discriminative efficiency at the same relatively low point (1 c.p. - 2 c.p.) found by McDougall for reaction time. Moreover, a very similar explanation will be offered, viz. that this relatively low "optimum" brightness is very probably due to certain distractions attending the attentive processes.

I The Technique of the Experiments.

The apparatus governing the experiments consists essentially of a Bowitsch-Boltzar Contact clock, a Wundt Demonstration-Memory Apparatus and a Jastrow Fall-Shutter apparatus as modified by Kuhlman. The cooperation of the apparatus is illustrated in Figure 1, which gives a schematic plan of the arrangement. To minimize distraction, the operating switch and memory apparatus were placed in a dark room, the clock and the modified fall-shutter in an adjoining room. The dotted lines (Fig.1) 1, 2, 3, 4 and 5 indicate the separation of these rooms, except that a vacant room intervenes between the two mentioned rooms.

The clock (K) makes two contacts for every complete swing of the pendulum. When the switch (S) is closed (in position shown) the current is allowed to flow through the magnets, p and p', which attract the armature, d, which in turn operates the ratchet wheels, r and r'. Upon the periphery of these wheels are extended points which come in contact with brushes s and s'. The contacts of these points with the brushes close the circuits, e and e', alternately (ratchet wheels r and r' closing respectively circuits e and e'). Circuits e and e' are connected through the magnets p_1 and p_2 of the memory apparatus, W. The armatures, c and c' of the magnets p_1 and p_2, are attached to the releasing mechanism, R. Closing circuit, e, induces the rotation of the disk (D) by the withdrawal of the armature, c. This brings the normal stimulus (N) into position. The comparative stimulus (C) is automatically brought into position by closing circuit, e' (at contact r') which operates the withdrawal of armature, c'. The operating force of the disk is supplied by means of a chain and weight (H).

The time interval of the normal and comparative stimuli is determined by the spacing of the contact points of the ratchet wheels, r and r', and upon the length of the period of the pendulum.

Details of the stimulus aperture (S), of the rotating disk (D), and the illuminating box (B) are diagramatically shown in II of Figure 2. Part I shows the same details in cross section.

The disk is constructed of light zinc pierced with twelve rectangular apertures corresponding in position and securely fastened to the twelve aluminum arms of the Wundt Memory Apparatus (W).

The rectangularslit (S) is 10 mm. wide and 40mm. long for the normal stimulus, By means of a shutter, i, secured in place by a thumbscrew, h, the length of the slit may be varied to suit the desired values of the comparative stimulus. The width of the slit remains constant for both normal and comparative stimuli, while the width and length of the norm remain constant for all experiments.

Behind the stimulus aperture (S), is stationed a dark box (B) containing a lamp of the desired c.p. employed in a given series of experiments. An opening somehwat larger than the aperture, and directly behind it, is provided in the box (O, part I). This opening is covered with tracing cloth which diffuses the light.

A discrepancy exists between the photometric measurements of the 80 c.p. tungsten lamp and the 50 c.p. carbon filament lamp. According to the measurements, the intensity of the illuminated area (O, Part I, Fig. 2) for the latter lamp enormously exceeds that of the former. A similar discrepancy exists between the measurements of the 2- and 4 c.p. lamps. In this case, the illumination for the former lamp approaches that of the latter. The explanation of these apparent variations is found in the position of the lamps in the dark box

and in the size of the lamps. The center of maximum illumination of the 50 c.p. lamp, because of its smaller size and higher position in the dark box, fell approximately into the center of the illuminated area of the box. The tungsten lamp, on the other hand, being much larger, finds its center of maximum illumination well below the illuminated area of the dark box. The near approach of the photometric measurements of the 2 c.p. lamp to that of the 4 c.p. lamp is explained upon the same basis. These photometric measurements were made by the ordinary method with a Bunson photometer.

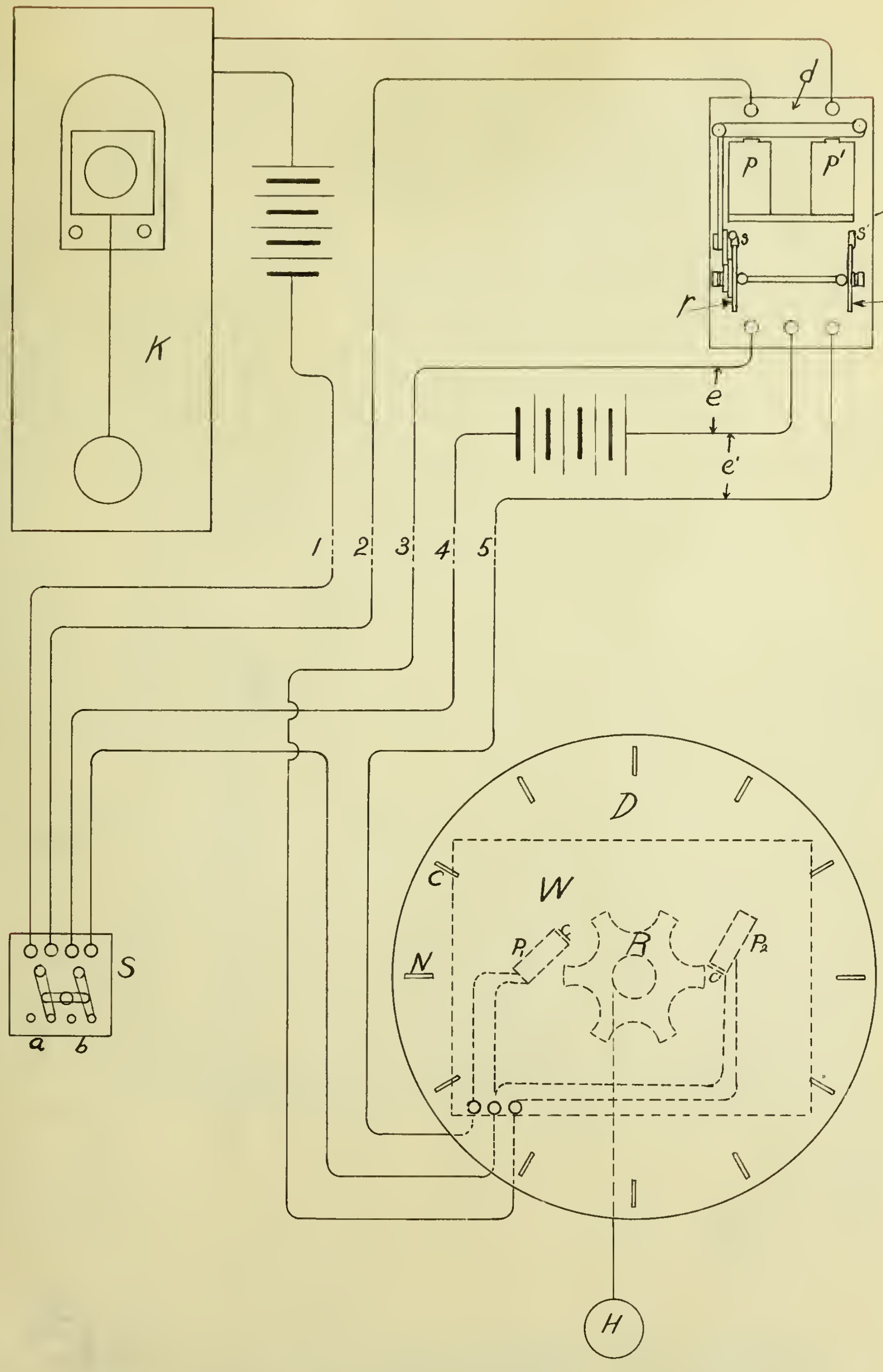

Fig. 1. Schematic Arrangement of Apparatus.

P.R.D.

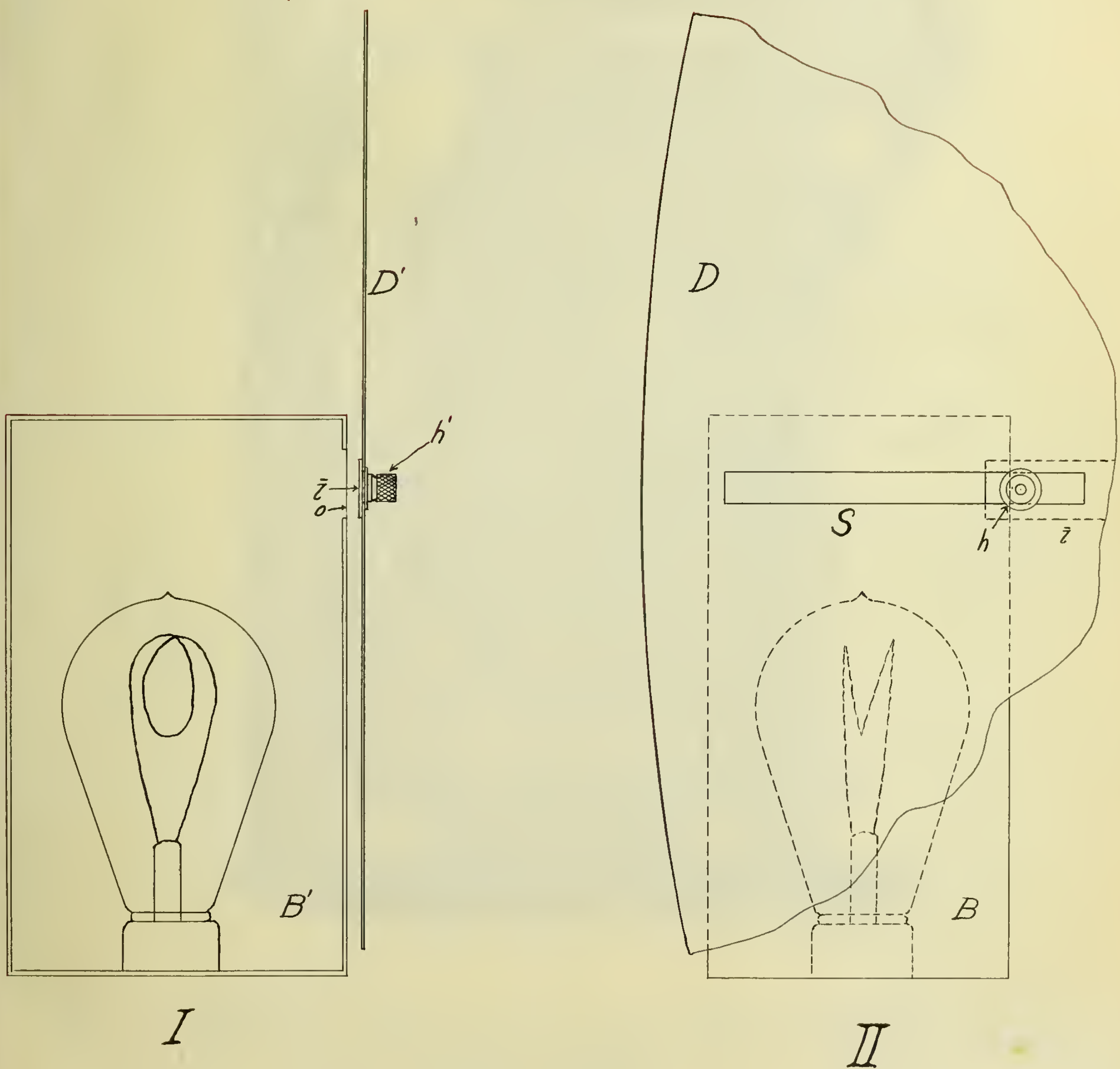

Fig. 2. Profile (I) and Sectional (II) Views of the Stimulus Aperture (N, Fig.1.) and Illumination Box.

P.R.D.

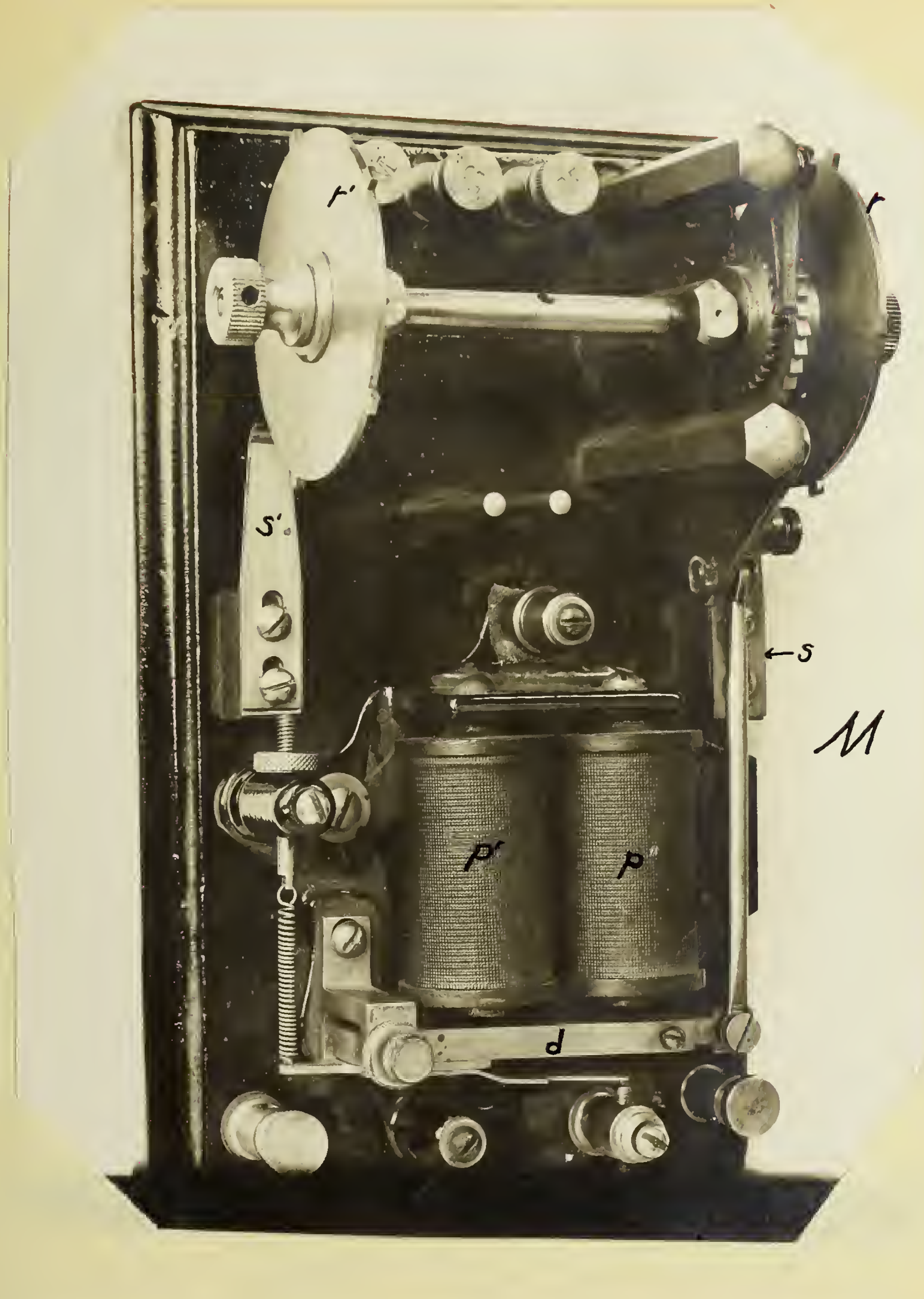

Fig. 3. Electrical Apparatus for Time Interval Control. (M,Fig.1.)
(After Kuhlman.)

II Method.

Those who served as observers in this experiment are; Sophie Rogers (A), W.R. Madden (B), the writer (C) and Lulu Dexter (D). B and D had never served as observers, while A had served as "O", and C as both "E" and "O" in a memory experiment during the winter of 1909-1910.

The Wundtian Method of Minimal Changes was employed throughout. A, B and D were entirely ignorant of the purpose and plan of the experiment. To express their judgments in terms of "greater," "equal", or "less", and to give an introspective analysis of their judgments whenever possible constitute the sole instructions given. However, after a few weeks of observation, all reported an awareness of the general run of the experiment, i.e., that it was a study of length discrimination under different degrees of illumination.

The observations were taken in a dark room. After an "adaptation" period of from five to ten minutes, "O" faced the rotating disc, at a distance of 6.5 feet. The stimuli were rectangular apertures, constant in width, varying in length, illuminated by lamps of ½, 1, 2, 4, 8, 16, 32, 50, 80 and 100 c.p. These stimuli were presented in pairs, each pair consisting of a "norm" (N)[1], and a "comparative" (C)[2]. Each pair constitutes a single experiment and six pairs make up a series. A slight pause was given after each ~~single~~ set of experiments for the purpose of resting "O"'s eyes. All

(1) N::width = 10 mm., length = 40 mm.

(2) C;:width = 10 mm., length = (N+x) or (N-x). X is a constant increment or decrement, its value being .25 mm. for observers B and D, and .5 mm. for A and C, who, with x = .25 mm., did not reach a point (within the series of six pairs possible with this apparatus) where all their judgments were either "greater" or "less".

judgments are recorded in terms of "greater" (>), "equal" (=) and "less" (<). Very often O's judgment is made <u>during the exposure</u> of of the second member of the pair rather than <u>after its completion</u>[(1)]. About 120 judgments are taken at each sitting, 30 in each of four different series.

These four different types of series are arranged as indicated in the table below.

Pair ↓	Series I		Series II		Series III		Series IV	
1	N	C-40.25 mm.	N	C-41.5 mm.	N	C-39.75 mm.	N	C-38.5 mm.
2	"	"-40.5 "	"	"-41.25 "	"	"-39.5 "	"	"-38.75 "
3	"	"-40.75 "	"	"-41.0 "	"	"-39.25 "	"	"-39.0 "
4	"	"-41.0 "	"	"-40.75 "	"	"-39.0 "	"	"-39.25 "
5	"	"-41.25 "	"	"-40.5 "	"	"-38.75 "	"	"-39.5 "
6	"	"-41.5 "	"	"-40.25 "	"	"-38.5 "	"	"-39.75 "

Series I proceeds from a condition of apparent equality to a clearly perceptible condition of "greater"; II, from a clearly perceptible condition of "greater" down to apparent equality; III, from apparent equality to "less"; and IV, from "less" to apparent equality.

Two time-orders were employed in the judgments obtained from A and B, while for C and D only the first was used. In the first time-order (T_1), N is the first member of the pair, C the second. In the

(1) Myers is rather inclined to take exception to these "immediate" judgments, as he terms them, contending that they involve no true comparison, no passing from 1st to 2nd stim., back to 1st, etc. (Yet this very "true comparison", this "passing back and forth" invites the entrance of a disturbing factor, the fading of the memory patterns, their loss in accuracy, the consequent indecision and the "guess" element.)
Myers. C.S. Text-book of Exper. Psych., p. 266.

second time-order (T_2) their respective positions are reversed. In all cases the judgments are given on C.

By this method over 7200 judgments were recorded. Below is a series taken at random from the records:

"E" - C. "O" - D. Series I. T_1. 1 c.p.

40.25	40.5	40.75	41.0	41.25	41.5
>	=	=	>	>	>
=	=	<	>	>	>
<	=	<	>	>	>
>	=	=	<	>	>
<	>	>	>	>	>

The results were computed by the "Halbierung-Methode". The averages of the "greater", "less", and "equal" judgments are computed separately. The two former are then combined, and this in turn is combined with the equality average. The final result is O's discriminative efficiency under the given conditions. In cases where aperfect score is obtained the average is placed midway between N and the smallest C used. Take for example, the following:

"E" - C. "O" - B. T_2 Series I. 4 c.p.

40.25	40.5	40.75	41.0	41.25	41.5
>	>	>	>	>	>
>	>	>	>	>	>
>	>	>	>	>	>
>	>	>	>	>	>
>	>	>	>	>	>

etc.

The average would be taken as 40.125 mm., or halfway between N (40 mm.) and the smallest C (40.25).

III. Results of the Experiments.

In the tables that follow are indicated the results of the investigation. Each table contains averages from 1200 judgments, 120 for each of the ten lights used.

TABLE I

"E"-C "O"-A T_1.

Brightness Intensity	Series I	Series II	Series III	Series IV	Average I & II	Average III & IV	Increment	Decrement	Average
½ c.p.	41.29	41.24	39.75	39.12	41.26	39.43	1.26	.57	.91
1 c.p.	41.17	41.20	39.75	39.75	41.18	39.75	1.18	.25	.71
2 c.p.	40.80	40.71	39.34	39.73	40.75	39.54	.75	.46	.60
4 c.p.	41.13	41.12	39.10	39.34	41.12	39.22	1.12	.78	.95
8 c.p.	41.13	41.27	38.85	39.11	41.20	38.98	1.20	1.02	1.11
16 c.p.	41.27	40.87	38.60	38.51	41.07	38.55	1.07	1.45	1.26
32 c.p.	41.36	40.94	39.35	39.05	41.15	39.20	1.15	.80	.97
50 c.p.	41.23	41.45	39.75	39.36	41.34	39.55	1.34	.45	.89
80 c.p.	41.49	41.27	39.75	39.75	41.38	39.75	1.38	.25	.81
100c.p.	41.42	40.90	39.36	39.75	41.16	39.55	1.16	.45	.80

TABLE II

"E"-C "O"-A T_2

Brightness Intensity	Series I	Series II	Series III	Series IV	Average I&II	Average III&IV	Increment	Decrement	Average
½ c.p.	40.65	41.00	38.58	38.69	40.82	38.63	.82	1.37	1.09
1 c.p.	40.63	40.25	38.98	39.19	40.44	39.08	.44	.93	.68
2 c.p.	40.63	40.25	39.07	39.03	40.44	39.05	.44	.95	.69
4 c.p.	40.87	40.65	39.01	38.80	40.76	38.90	.76	1.10	.93
8 c.p.	41.32	40.87	38.42	38.79	41.09	38.60	1.09	1.40	1.24
16 c/p.	40.99	40.70	39.00	39.05	40.84	39.02	.84	.98	.91
32 c.p.	40.87	40.25	38.67	38.54	40.56	38.60	.56	1.40	.98
50 c.p.	40.65	40.63	38.74	38.53	40.64	38.63	.64	1.37	1.00
80 c.p.	40.25	40.25	38.81	38.64	40.25	38.72	.25	1.28	.76
100 c.p.	40.65	40.63	38.59	38.65	40.64	38.62	.64	1.38	1.01

TABLE III

"E"-C "O"-B T_1

Brightness Intensity	Series				Average		Increment	Decrement	Average
	I	II	III	IV	I&II	III&IV			
½ c.p.	40.85	40.47	39.08	39.12	40.66	39.10	.66	.90	.78
1 c.p.	40.73	40.83	39.29	39.09	40.78	39.19	.78	.81	.79
2 c.p.	40.87	40.12	39.87	39.87	40.49	39.87	.49	.13	.31
4 c.p.	40.76	40.83	39.87	39.87	40.79	39.87	.79	.13	.46
8 c.p.	40.51	40.52	39.45	39.87	40.51	39.66	.51	.34	.42
16 c.p.	40.64	40.79	39.87	39.87	40.71	39.87	.71	.13	.42
32 c.p.	40.67	40.73	39.29	39.37	40.70	39.33	.70	.67	.68
50 c.p.	40.68	40.90	39.52	39.16	40.79	39.34	.79	.66	.72
80 c.p.	40.87	40.71	39.52	39.04	40.79	39.28	.79	.72	.75
100 c.p.	40.84	40.74	39.19	39.27	40.79	39.23	.79	.77	.78

TABLE IV

"E"-C "O"-B T_2

Brightness Intensity	Series				Average		Increment	Decrement	Average
	I	II	III	IV	I&II	III&IV			
½-c.p.	40.75	40.69	39.38	39.14	40.72	39.26	.72	.74	.73
1 c.p.	40.87	40.48	39.24	39.23	40.67	39.23	.67	.77	.72
2 c.p.	40.12	40.62	39.53	39.58	40.37	39.55	.37	.45	.41
4 c.p.	40.12	40.85	39.26	38.91	40.48	39.08	.48	.92	.70
8 c.p.	40.37	40.50	39.28	39.26	40.43	39.27	.43	.73	.58
16 c.p.	40.12	40.12	39.25	39.25	40.12	39.25	.12	.75	.43
32 c.p.	40.45	40.57	39.30	39.19	40.51	39.24	.51	.76	.63
50 c.p.	40.66	40.88	39.29	39.38	40.77	39.33	.77	.67	.72
80 c.p.	40.37	40.12	39.19	39.15	40.24	39.17	.24	.83	.53
100 c.p.	40.87	40.86	39.12	39.31	40.87	39.21	.87	.79	.83

TABLE V

"E"-F* "O"-C T_1

Brightness Intensity	Series I	Series II	Series III	Series IV	Average I&II	Average III&IV	Increment	Decrement	Average
½ c.p.	42.13	41.17	38.43	38.87	41.46	38.65	1.46	1.35	1.40
1 c.p.	40.94	41.25	38.79	38.55	41.09	38.67	1.09	1.33	1.21
2 c/p.	41.37	41.25	38.75	38.92	41.31	38.83	1.31	1.17	1.24
4 c.p.	41.64	41.54	39.21	38.75	41.59	38.98	1.59	1.02	1.30
8 c.p.	41.60	41.28	38.81	38.75	41.44	38.78	1.44	1.22	1.33
16 c.p.	41.39	41.48	38.70	38.82	41.43	38.76	1.43	1.24	1.33
32 c.p.	40.86	40.97	39.05	38.32	40.91	38.68	.91	1.32	1.12
50 c.p.	41.68	41.06	38.75	38.47	41.37	38.61	1.37	1.39	1.38
80 c.p.	41.43	41.25	38.57	38.92	41.34	38.74	1.34	1.26	1.30
100 c.p.	41.57	41.41	38.58	38.44	41.49	38.51	1.49	1.49	1.49

* F. - Dr. A.H. Sutherland.

TABLE VI

"E"-C "O"-D T_2

Brightness Intensity	Series I	Series II	Series III	Series IV	Average I&II	Average III&IV	Increment	Decrement	Average
½c.p.	40.71	40.47	39.18	39.42	40.59	39.30	.59	.70	.64
1 c.p.	40.66	40.76	39.45	39.41	40.71	39.43	.71	.57	.64
2 c.p.	40.60	40.33	39.19	39.25	40.46	39.22	.46	.78	.62
4 c.p.	40.98	40.52	39.30	39.34	40.75	39.32	.75	.68	.71
8 c.p.	40.35	40.41	39.31	39.24	40.38	39.27	.38	.73	.55
16 c.p.	40.60	40.33	39.11	39.43	40.46	39.27	.46	.73	.59
32 c.p.	40.37	40.50	39.31	39.11	40.43	39.21	.43	.79	.61
50 c.p.	40.50	40.68	39.07	39.29	40.59	39.18	.59	.82	.70
80 c.p.	40.44	40.42	39.18	39.38	40.43	39.28	.43	.62	.52
100c.p.	40.12	40.59	39.52	39.47	40.35	39.49	.35	.51	.43

From the contents of Tables I - VI are drawn the curves shown in Figues 4 - 14. Figures 4 - 7 give a graphic representation of the course of A's discriminative ability, Fgiures 8 - 11 B's and 12 -13 C's and D's respectively. The curves are numbered in the following manner.

Figure 4 (1_a - T_1, incremental
(2_a - T_2, "
" 5 (1_b - T_1, decremental
(2_b - T_2, "
" 6 (1_c - T_1 (1_a and 1_b combined)
(2_c - T_2 (2_a and 2_b ")
" 7 (d - 1_c and 2_c combined) A

Figure 8 (1_e - T_1, incremental
(2_e - T_2, "
" 9 (1_f - T_1, decremental
(2_f - T_2, "
" 10 (1_g - T_1, (1_e and 1_f combined)
(2_g - T_2, (2_e " 2_f ")
" 11 (h - 1_g and 2_g combined) B

(1_i - T_1, incremental)
(1_j - T_1, decremental) D
Figure 12 (1_k - T_1, incremental)
(1_l - T_1, decremental)) C

Figure 13 (1_m - T_1, 1_i and 1_j combined) D
(1_n - T_1, 1_k " 1_l ") C

Below each c.p. in the figures is given the relative value of that lamp as shown by the photometric measurements.

Fig. 4.

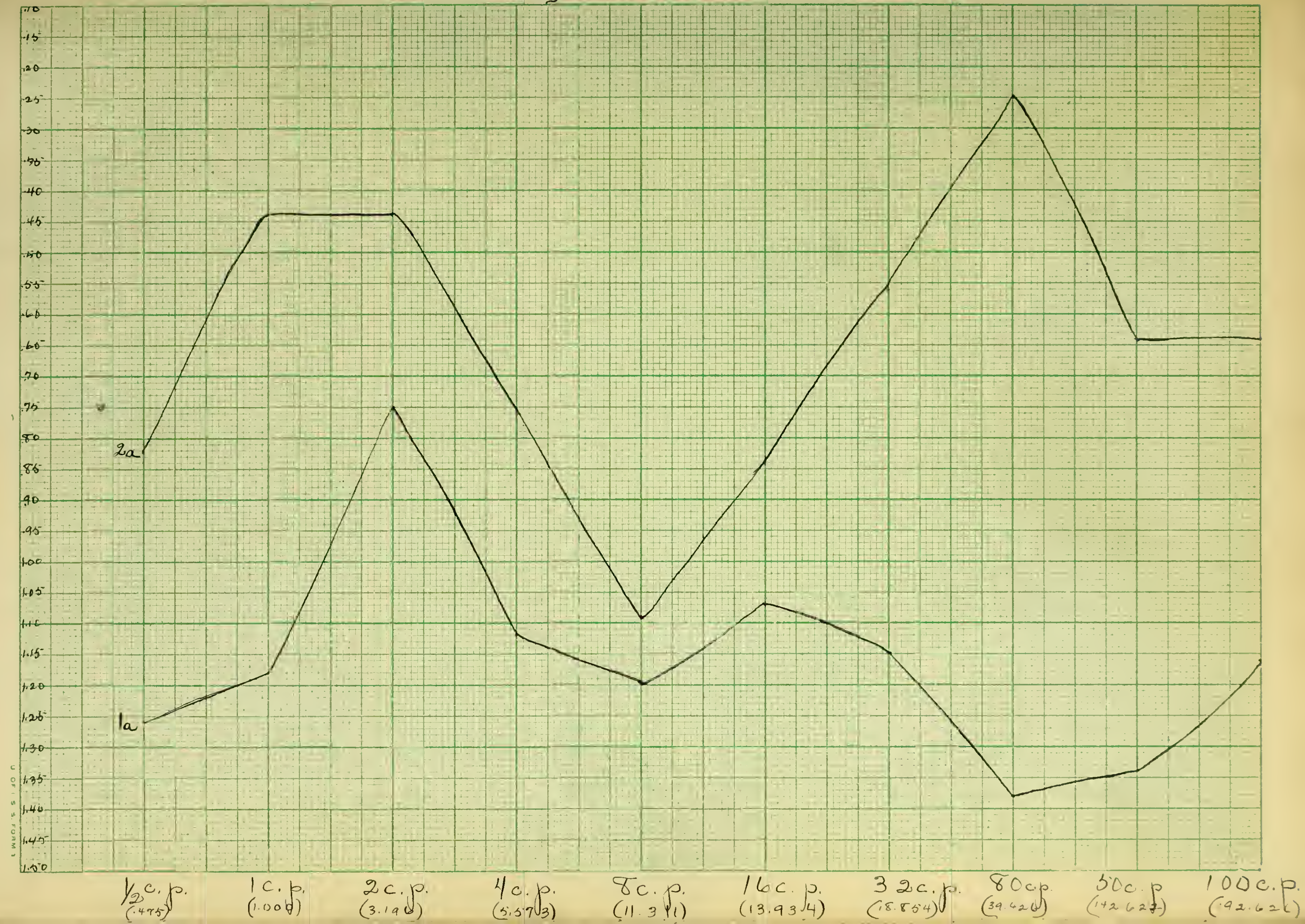

Fig. 5


1b
2b
½ c.p. (.475)
1 c.p. (1.000)
2 c.p. (3.196)
4 c.p. (5.573)
8 c.p. (11.311)
16 c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142 622)
100 c.p. (192 626)

Fig. 6


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1.00
1.05
1.10
1.15
1.20
1.25
1.30
1.35
1.40
1.45
1.50
1c
2c
1/2 c.p. (.475)
1 c.p. (1.006)
2 c.p. (3.196)
4 c.p. (5.573)
8 c.p. (11.311)
16 c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142.622)
100 c.p. (192.626)

Fig. 7.

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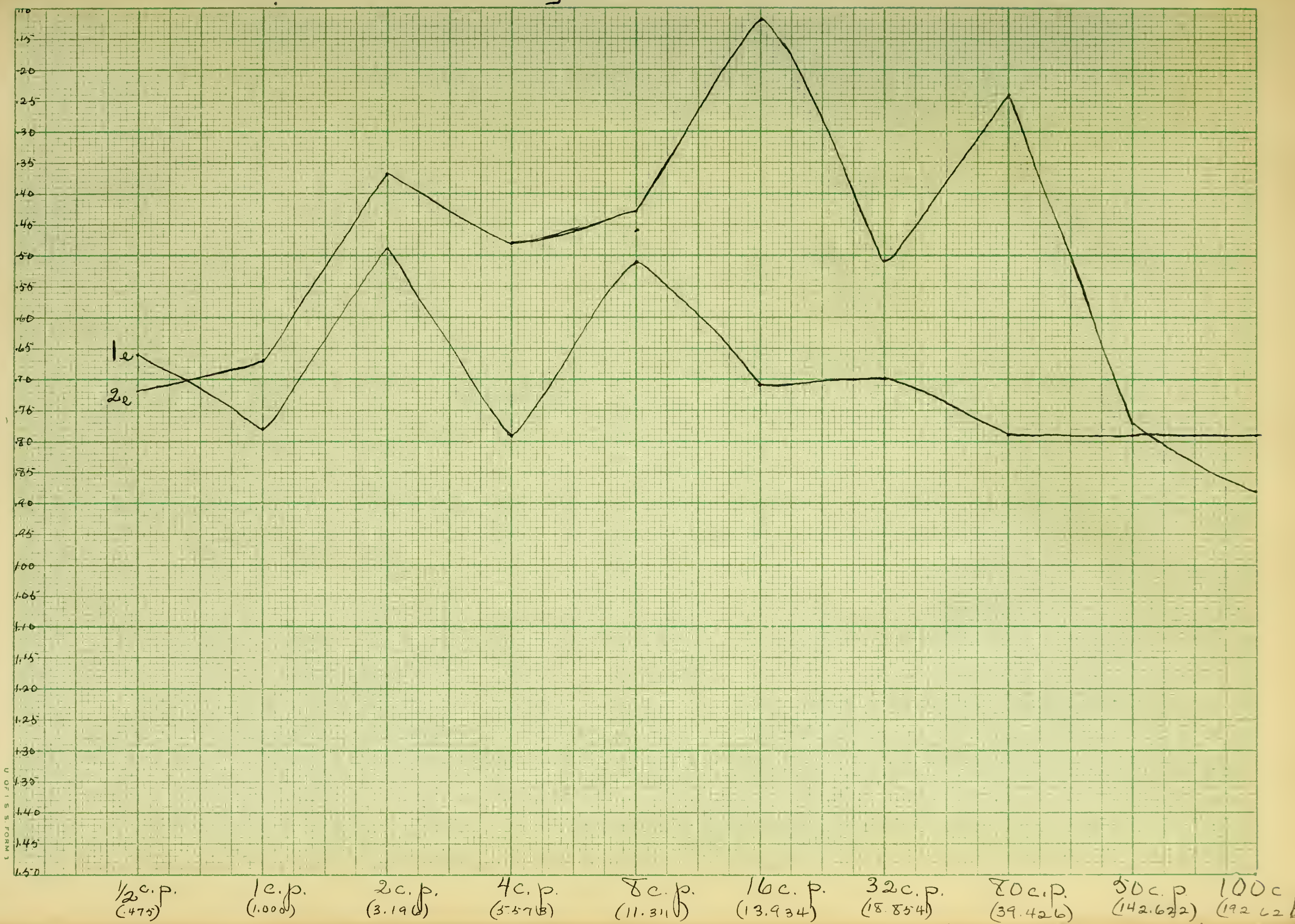
1.30
1.35
1.40
1.45
1.50
d
½c.p. (.476)
1c.p. (1.000)
2c.p. (3.196)
4c.p. (5.573)
8c.p. (11.311)
16c.p. (13.934)
32c.p. (18.854)
80c.p. (39.426)
50c.p. (142.627)
100c.p. (92.626)
U OF I S S FORM 3

Fig. 8.



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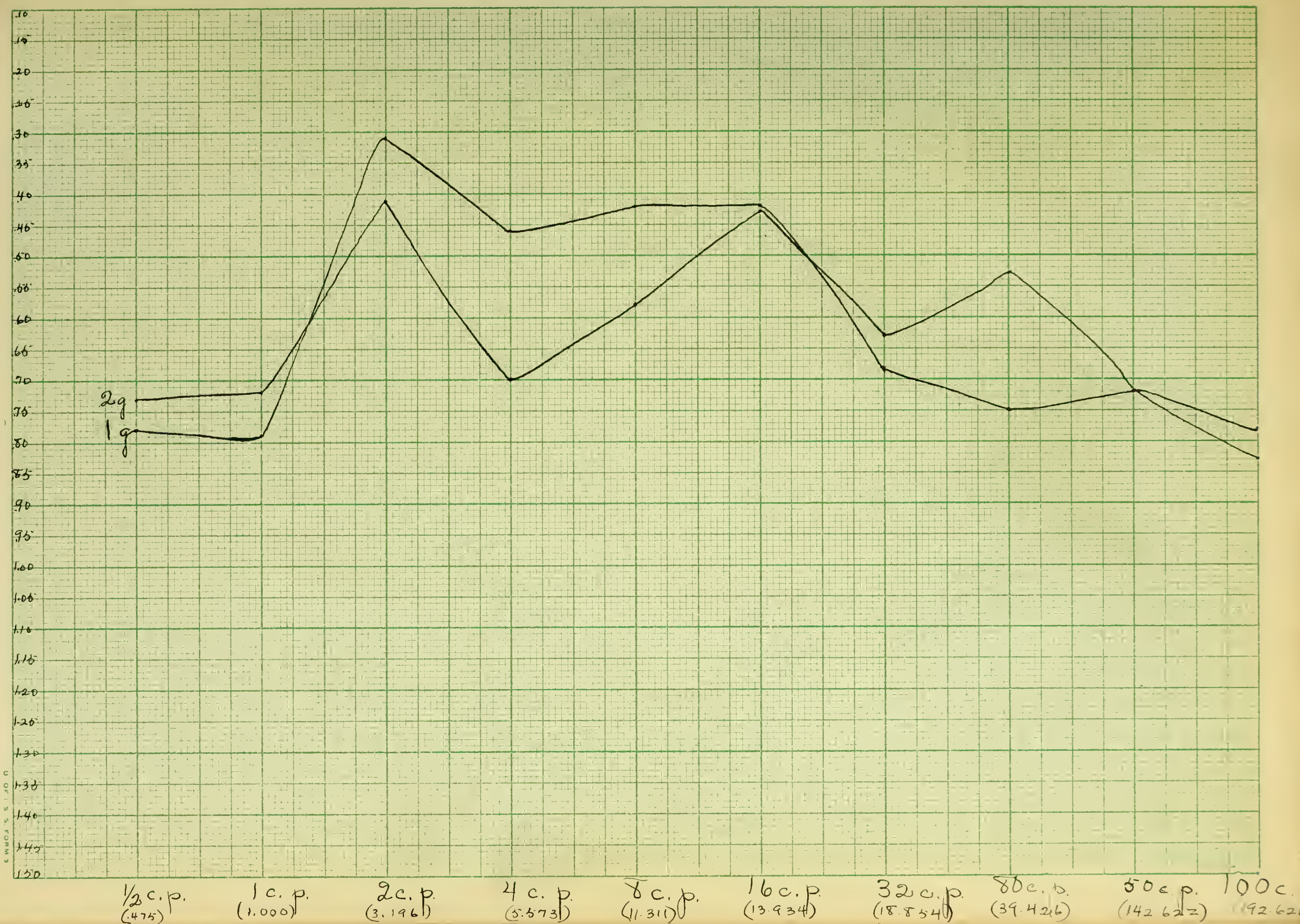
1.05
1.10
1.15
1.20
1.25
1.30
1.35
1.40
1.45
1.50
1e
2e
1/2 c.p. (.475)
1 c.p. (1.000)
2 c.p. (3.190)
4 c.p. (5.578)
8 c.p. (11.311)
16 c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142.622)
100 c
U OF I S S FORM 3

Fig. 9

2f
1f
1/2 c.p. (475)
1 c.p. (1.000)
2c.p. (3.196)
4c.p. (5.573)
8c.p. (11.311)
16c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142.622)
100 c.p. (192.626)

Fig. 10.



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1/2 c.p. (.475)
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2 c.p. (3.196)
4 c.p. (5.573)
8 c.p. (11.311)
16 c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142.622)
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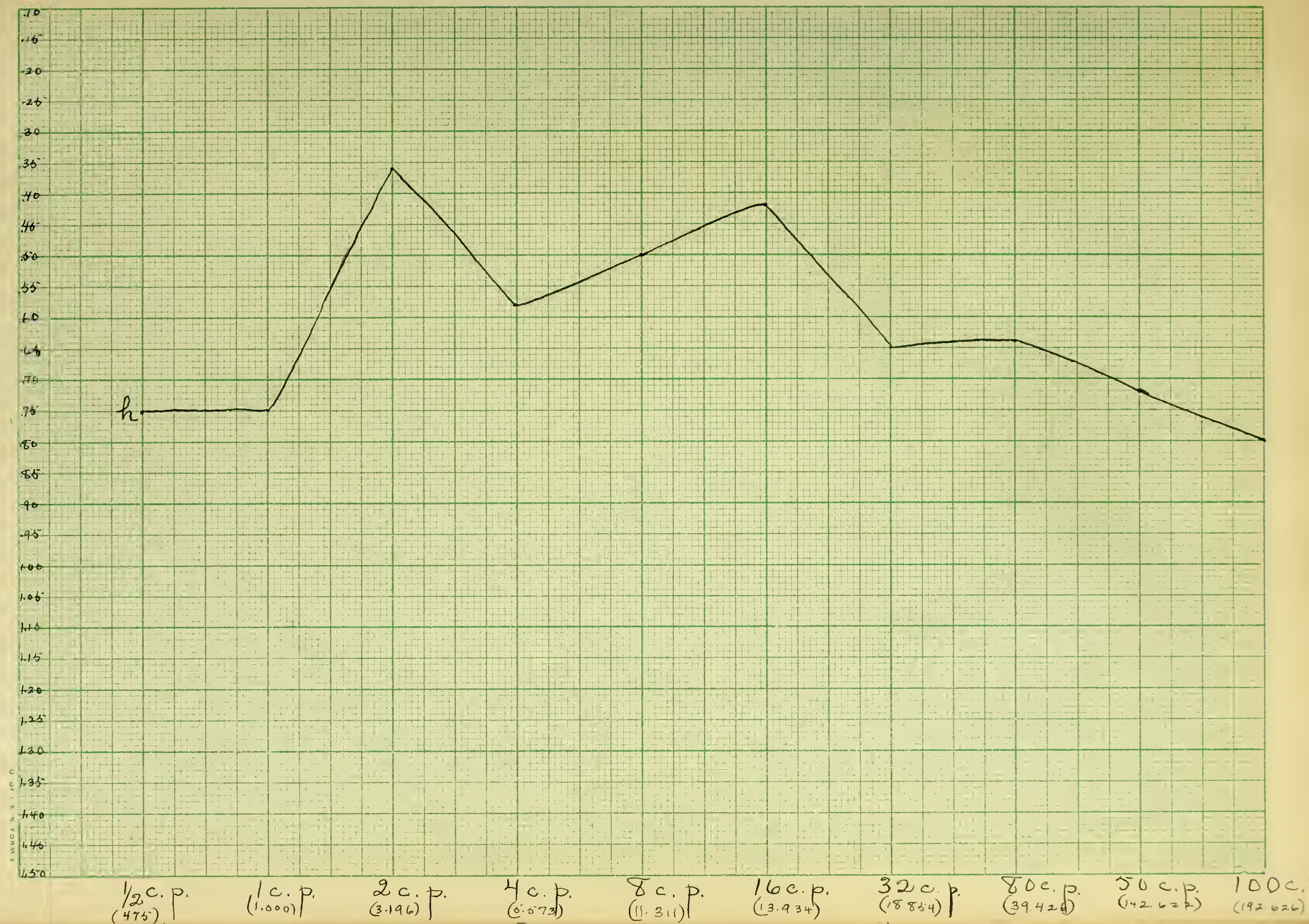
U OF I S S FORM 3

Fig. 11.



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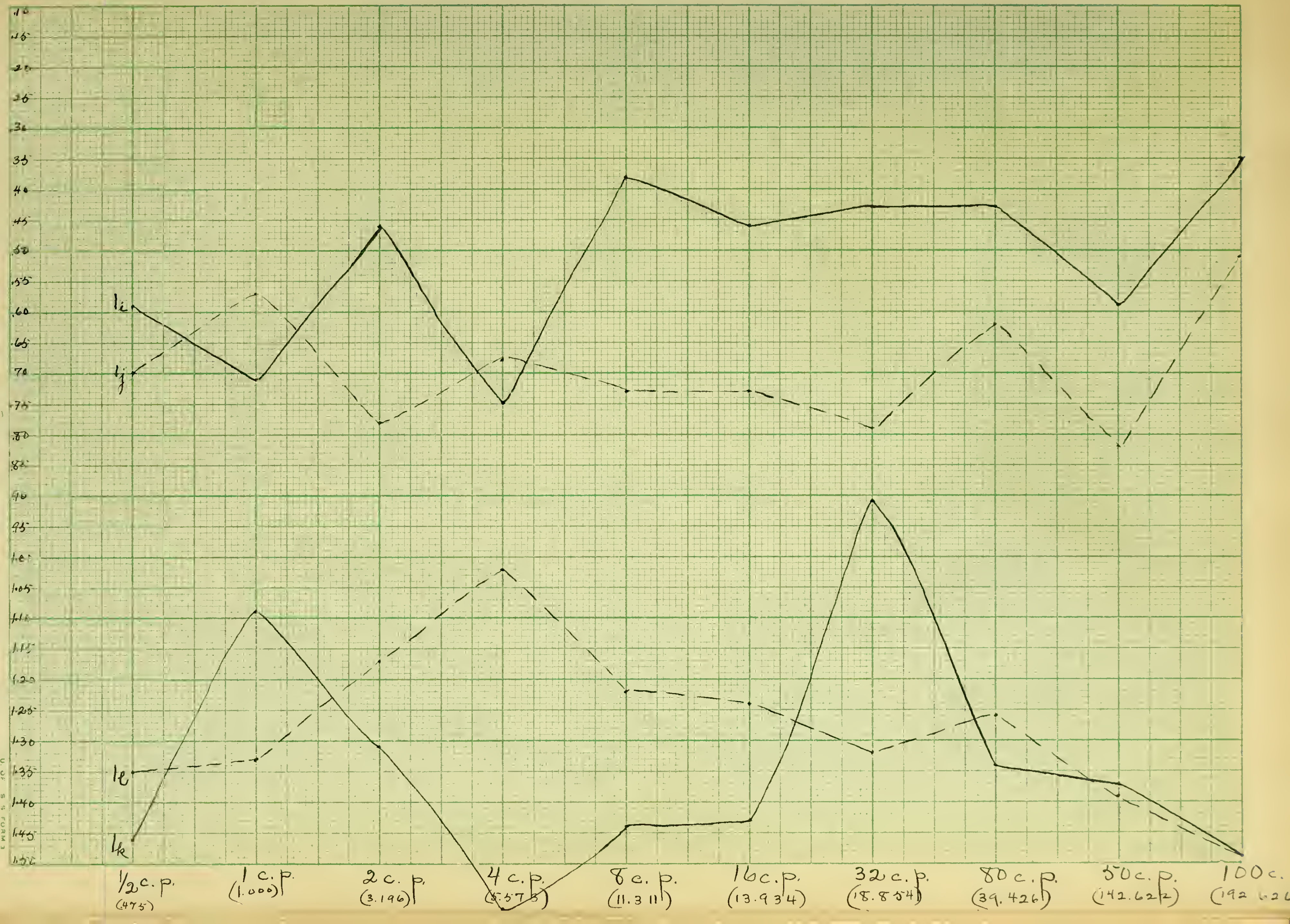
1 c. p. (1.000)
2 c. p. (3.196)
4 c. p. (6.573)
8 c. p. (11.311)
16 c. p. (13.934)
32 c. p. (18.854)
80 c. p. (39.424)
50 c. p. (142.627)
100 c. (192.626)

Fig. 12



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l_i
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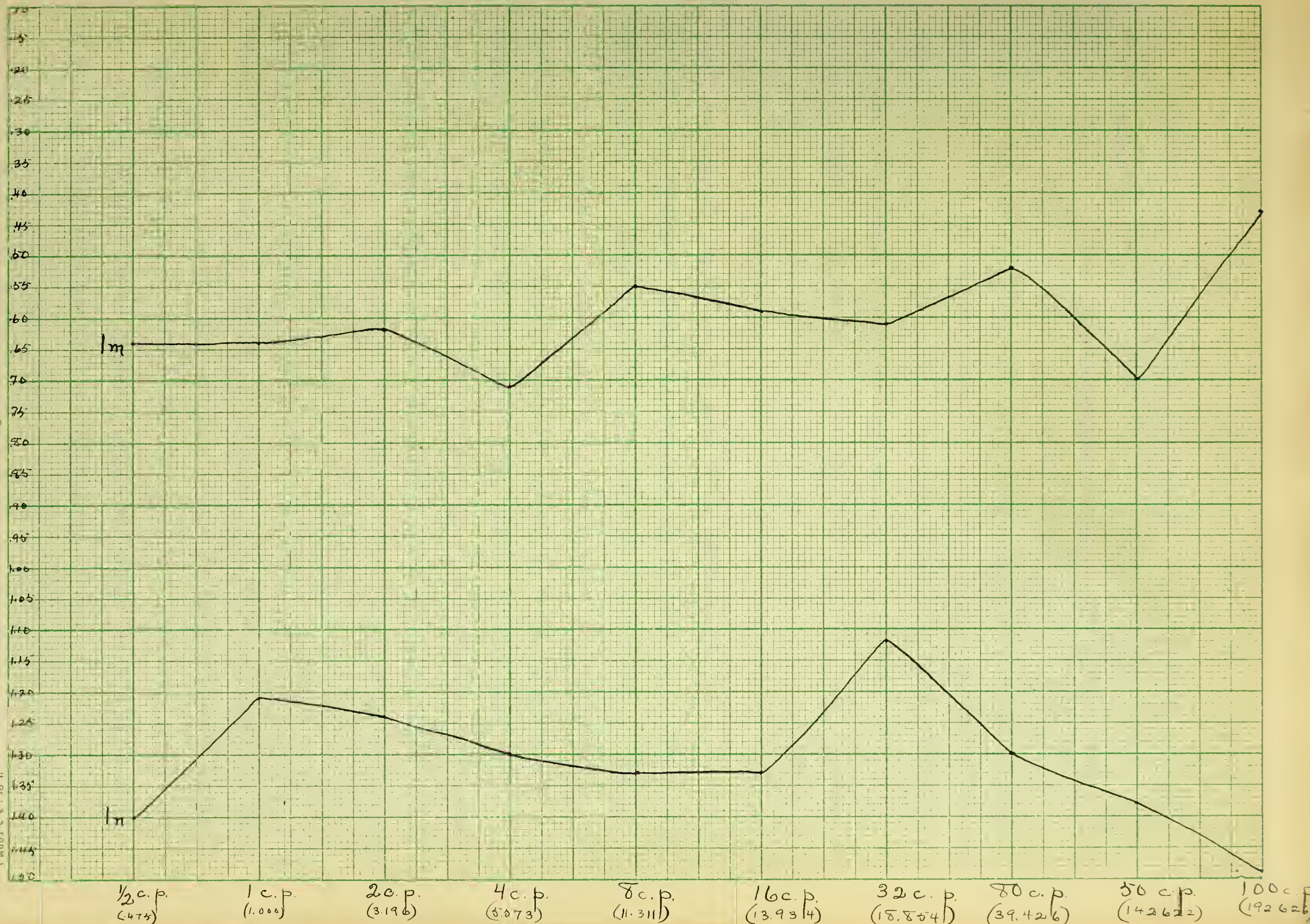
1/2 c.p. (475)
1 c.p. (1.000)
2 c.p. (3.196)
4 c.p. (5.575)
8 c.p. (11.311)
16 c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142.622)
100 c.

Fig. 13.



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2 c.p. (3.196)
4 c.p. (5.073)
8 c.p. (11.311)
16 c.p. (13.934)
32 c.p. (18.854)
80 c.p. (39.426)
50 c.p. (142622)
100 c.p. (192626)

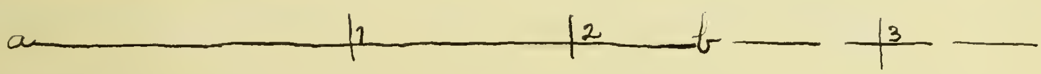
Tables I, II and V, first time-order results, show increment values greater than decrement values in 23 cases, equal in 1, less in 6. Tables II and IV, on the other hand, second time order, show, in 19 out of the 20 cases, increment values less than decrement values. The first time-order indicates a lower threshold in decremental than in incremental series, and the second time-order vice-versa. In the introspective data obtained from A this statement occurs several times, "It is so much easier to judge when the second member is less than the first." This"feeling of easier", it may be seen, coincides with greater efficiency, since, in either time-order, the observed increment and decrement values, respectively,are lower when the second member of the pair is less than the first. Table VI (O - D), however, shows the reverse to be true, i.e. the increment values are less than the decrement in 8 cases out of the 10.

An attempt to explain this variation of D on the basis of different methods of comparison fails, since B, C and D agree in their description of how the judgments were made. In the case of B, C and D, during the exposure of the first member, the rectangular stimulus is grasped as a whole and retained as a mental image which is "laid on" the second member when it appears. The judgment is given according to whether the second member of the stimulus pair extends beyond, coincides with, or falls short of, this "pattern" image. They report absolutely no awareness of eye-movements. A, however, repeatedly describes the process of comparison as consisting of eye-movements, a "running along" the lower edge of the rectangle. Evidently the kinaesthetic element connected with the eye-movements forms the basal element in A's judgments.

The first time-order shows a negative time-error in the direc-

tion of increase, a positive error in the direction of decrease. (Figures 4 and 7, 5 and 8.) The combination of the incremental and decremental curves shows a neutralization of the time-error. (Figures 6 and 10.)

The observers frequently gave their judgments immediately upon the exposure of the second member of the stimulus pair, not waiting for the full duration. Obviously the stimulus duration, effective in producing the judgment, is a variable factor. To illustrate, suppose the line a - b in the accompanying figure represents the duration of the stimulus. Any judgment falling on the line a - b, prior to its completion, must necessarily be based on sensory elements of less intensity than that intended by the experiment, provided point b, of the hypothetical line (a - b) represents the maximum effect of the stimulus. Let 1, 2 and 3 represent different periods at which judgments were expressed, during, or after the exposure.



If the judgment falls at 1, obviously O has not received the maximum effect of the lamp in use. According to Lough[1] such a judgment should be counted as resulting from a sensation corresponding to a lamp of lower intensity. In other words judgments should not be made until an interval has elapsed sufficient to produce the maximum effect of each lamp.

This has no practical validity. The objective , conditioning factors involved in a judgment may be controlled with a fair degree

(1) "A strong stimulus acting for half the time necessary to produce its maximum effect, gives rise to a sensation of exactly the same intensity as that produced by half as strong a stimulus producing its maximum effect." Lough, Jas. E. Relation of Intensity to Duration of Stimulus in Sensations of Light. Psych. Rev. 1896, III, 484. (Harv.)

of accuracy; the culminating period of a judgment in expression is subjective, and in large measure beyond control. Only accidentally, and at rare intervals, do the completion of the stimulus, upon which the judgment is expressed and the appearance of the judgments in consciousness, coincide. A large element of spontaneity enters into every judgment, however much, as in cases of doubt, it appears restricted or hedged about. The exposure periods of the normal and comparative stimuli and the time-interval between them were empirically determined to the satisfaction of each reagent. The fluctuations in the time of formation of a judgment are subjective and uncontrollable; the time of expression, however, may be definitely controlled. On the side of accuracy it appears best to permit O to express his judgment at the time of formation. Any undue restriction or demand as to the time of expression may seriously affect accuracy in a judgment.

Careful examination of the various curves reveals a very decided rise and fall in the course of discriminative ability in the case of A, B and C. Curves 1_c, 1_g, and 1_n, representing the course of A, B and C's efficiency as obtained from first-time order results, show two distinct maxima in discriminative ability, one falling at approximately 2 c.p. illumination (3.196) for A and B and between 1 and 2 c.p. for C, the other appearing at approximately 80 (39.426) c.p. for A, 16 (13.934) c.p. for B, and 32 (18.854) c.p. for C. The final maximum for A and B falls at 2 c.p., for C at 32 c.p. Curves d and h, representing the course of A and B's ability as indicated by results from both time-orders, emphasize still further the indication of two points of maximal efficiency, one at a relatively low intensity (1 - 2 c.p.) and a second falling at approximately 16 c.p. for B

and a somewhat greater intensity for A. The high efficiency at 2 c.p. is probably due to the influence of this low degree of illumination upon the attentive process. The facts indicate that at this point the unusual condition is just sufficient distraction to intensify the attention, and consequently raise the efficiency. Whereas a still lower intensity increases the difficulty of the task to a point where the attention is depressed rather than stimulated.

The second maximum, which falls somewhere between 16 c.p. and 80 (39.4) c.p. is probably the effect of habituation, since this is approximately the illumination which the ordinary student is accustomed to use, so that his eyes are specially "adapted" or fitted to judge by it, while as the intensity is increased, physiological factors of strain, fatigue, etc., prove too great a distraction, interfering withaccurate discrimination. Moreover with the two highest intensities it was impossible to eliminate a certain amount of irradiation which easily proved a disturbing element.

D's curve (1_m) shows no particularly significant points, rising and falling quite irregularly. A study of the introspective data reveals a lack of concentration on the task in hand, and confirms the opinion that D offers an example of dispersed attention.

IV. Summary of Results.

Briefly stated the conclusions warranted by the results discussed above are as follows:

(1) The course of discriminative ability with visual stimuli of varying intensities shows a decided rise and fall.

(2) There are two maxima of discriminative efficiency, one at a relatively low intensity (2 c.p.) and a second at a rather mediate point (approximately 32 c.p.)

(3) The first time-order is favorable to a lower threshold in the direction of decrease than of increase. The second time-order is favorable to a lower threshold in the direction of increase than of decrease.

(4) In the first time-order the time error is negative in the direction of increase, positive in the direction of decrease.

(5) The time-order, therefore, is a more important factor in the determination of the threshold than the direction of difference.

(6) Attention and practice are the two factors most effective in determining discriminative ability.